Year 1 Report for NASA AISRP Grant NNG05GA94G

Project Title:
A Neural Map View of Planetary Spectral Images for Precision Data Mining and Rapid Resource Identification

Erzsébet Merényi, PI, Rice University
Robert H. Brown Co-I, University of Arizona, Tucson, AZ
William H. Farrand, Co-I, Space Science Institute, Boulder, CO
Thomas Villmann, Collaborator, Klinik für Psychotherapie, Universität Lepzig, Germany
Colin Fyfe, Collaborator, University of Paisley, Scotland

Project period: 11/1/2004 − 10/31/2007

Project URL: http://www.ece.rice.edu/~erzsebet/HYPEREYE.html

Contents

1 Project Summary (from original proposal)

This project follows up on a current three-year AISRP grant, NAG5-10432, which will end 8/2004. It addresses a pressing need for rapid yet intelligent analysis of voluminous multi- and hyperspectral images in order to extract key data and generate knowledge. Spectral imaging plays a leading role in remote identification of surface materials of Earth (Landsat, AVIRIS, Hyperion), Mars (Pathfinder, MGS, MER), the Jovian system (Galileo NIMS), the Saturnian system (Cassini VIMS) and other solar system bodies. Hyperspectral sensors, in particular, enable detailed identification through the complexity of signatures measured in hundreds of narrow spectral bands. The challenge in automated and fast (real time, on-board) interpretation of these huge images calls for massively parallel algorithms, as well as it requires sophisticated algorithms for optimal knowledge extraction. Properly utilized, Artificial Neural Networks (ANNs) can provide both.

    The current project engineered ANNs, specifically Self-Organizing Maps (SOMs) and their hybrids for efficient and sophisticated clustering and classification of spectral images, developing custom modules supported by commercially available components. Based on some of the latest theoretical research on SOMs, the tools we developed, jointly with European experts, are powerful for distinguishing a large number of spectral classes and for the discovery of "interesting" but uncommon and spatially very small classes. We use information theoretically principled SOM approaches, which increases power

and confidence in autonomous data mining. We demonstrated the effectiveness and high quality of data analysis on sample IMP spectral images, Cassini VIMS Jupiter fly-by imagery, AVIRIS and other data representing typical challenges in NASA's missions. We propose to advance these computational intelligence capabilities in three ways: 1) We will add significantly new theoretical strength to information extraction modules. 2) The software, HYPEREYE, will be made transferable to other users through high-level graphic interface, augmented software design, tutorials and wrapping, opening an important phase of technology infusion that will take recent and future developments into the user community. 3) We will directly participate, using our methods and software, in analyses of spectral images forthcoming from the Mars Exploration Rovers and Cassini VIMS Saturn orbital tour, and (pending its funding) a Pluto/icy satellites spectral analysis project.

The 'neural' core of our software is already suitable for implementation in high-speed massively parallel hardware (which could be an on-board analysis capability), as it was one of the original objectives of our work. We are pursuing that line of development outside of this project proposal and, if successful, we anticipate using the hardware to support this work as well.

This project is a collaboration between computer science and space science investigators at Rice University, University of Arizona, and the Space Science Institute, Boulder, CO.

2 Accomplishments in Year 1, 11/1/04 - 10/31/05

2.1 Completion of project tasks (algorithm and software development, data analysis)

Task 1: Work on the main GUI, data handling and other support layers Data handling capabilities were expanded for both the user and the developer. For users, modules were made to convert input data from a variety of binary and ascii formats to a unified internal binary format that can also contain meta data for each data element (spectrum, multi-dimensional image pixel). The meta data extension allows useful visualizations of spectra that have no spatial context, and helps data tracking (e.g., notes can be kept about unique processing on the level of individual spectra). For developers, the data handling code-object was made generic so that all vector, raster, network and meta data can be accessed through a unified interface. The addition of FITS reader was considered but not implemented due to lack of demand. Instead, comprehensive ascii and meta data format and content were designed and implemented to process planetary ice spectra for a joint project (AISRP NNG05GA63G, PI Eliot Young.)

We started a Year 2 task, the update of HyperEye modules to use QT, this year. The QT library's visualization components aided work in Task 3 and elsewhere, and it proved more efficient to move those as well as other attractive QT core data handling components to Year 1. The QT library now assists meta data parsing, and exporting of results to various graphic formats for publication. Later it will also help perform history recording of interactive user input during module operation. (We moved this history recording to Year 2 in light of completing the above, more essential task items). We developed a plug-in architecture for visualization early in the grant year, and later we extended it. Research on GRLVQ (see Task 2) gained efficiency from a special modification by extending the plug-in architecture we had developed previously for visualization methods, to modules using network learning algorithms.

Web demonstration of our main tools is at http://www.ece.rice.edu/~erzsebet/HYPEREYE.html, complete with online documentation, demo data sets and tutorial.

Task 2: Advancement of ANN/knowledge extraction algorithms: We further studied the capabilities of the SOM magnification algorithm (BDH) by Bauer, Der and Herrmann (1996). The BDH allows control of the magnification exponent α in the power law $Q(w) = const * P(v)^{\alpha}$. This power law has been proven to express the relationship of $Q(w)$, the density of SOM weight vectors (the quantization prototype vectors) in input data space, to $P(v)$, the density of the input data. $\alpha = 1$ therefore provides the information theoretically optimal (max. entropy) SOM mapping, and $\alpha < 0$ enlarges the SOM response areas for rarely occurring data, thereby increasing the chance of their discovery. This is a

potentially very powerful tool. However, since the theory can only provide analytical proof for 1-d data and for n-d data whose dimensions are statistically independent, we investigate its limits for data of increasing complexity with numerical simulations. Our results so far are very encouraging, and help gain deeper understanding of the strengths and weaknesses of the BDH scheme. Besides synthetic data, we showed on moderate-dimensional spectral images of Mars and Earth the knowledge discovery power of SOM magnification. Resulting papers are Merényi (2004), (2005), and Merényi, Jain, Villmann (2005).

In March, 2005, new graduate student Lily Zhang started systematic evaluation of the Topographic Function (Villmann *et al.*, 1997), a measure of the topology preservation in SOM mapping, to determine its suitability for high-dimensional data. No publications yet, but preliminary results look good. Lily is also implementing this (presently standalone) algorithm as a HyperEye module.

Graduate student Michael Mendenhall has been working with the PI on "relevance learning" with Generalized Relevance Learning Vector Quantization (Hammer and Villmann, 2002; Villmann *et al.*, 2003) to assess the relative importances of hyperspectral data dimensions. We investigate the GRLVQ because we have not seen good feature extraction for hyperspectral data, *i.e.*, schemes that preserve the distinction among the many classes that hyperspectral data is meant to distinguish. The GRLVQ is the first we know of to measure the quality of the feature selection by the classification accuracy on the same data. We found an instability in the Hammer and Villmann scheme, implemented a modified learning that stabilized the process and increased the classification accuracy and speed. We plan to submit a paper to the upcoming meeting of the Am. Soc. of Photogrammetry and Remote Sensing (Feb, 2006). Capt. Mendenhall is supported by the U.S. Air Force, his contributions are at no cost to this grant.

Dr. Villmann visited in March, 2005, during which time we had intense discussions about all three topics above, and finalized the journal paper Merényi, Jain and Villmann (2005).

Task 3: Improvement of visualization and human interaction Significant effort was spent on advancing our semi-manual Cluster Boundary Extractor (REMAP), complete with sophisticated visualization. Sample capabilities are illustrated at the HyperEye demo web site, see ann-SOMxxx and REMAP modules. Graduate student Kadim Tasdemir implemented various cluster visualizations (*e.g.*, Cottrell and DeBodt, 1996; and others, including the use of different metrics) and compared them to the widely used Ultsch and Siemon (1990) scheme in Year 3 of the previous grant. Building on that, this year he and the PI have been developing a highly automated method for cluster boundary extraction from converged SOMs. Fully automated solution does not exist. We believe that our current algorithm works better and is more automated than others, for high-dimensional data. Our paper (Tasdemir and Merényi, 2005) was accepted to the highly selective Workshop on Self-Organizing Maps (Paris, Sep 5-8, 2005).

Other visualization tasks included the automation of plotting class statistics collected by our CLSTAT module from classified or clustered spectral images, separately for each class. For many classes, it is a tedious chore to arrange the plots such that all graphs show appropriately (for example, properly offset for viewing), class labels or legends are placed where they should be, etc. Allen Geer, an undergraduate student wrote a sophisticated plotting package (HyperEye module "VECPLOT") that has the intelligence to accomplish the above, yielding great savings of time and effort in our data analyses.

Graphical display and manipulation is now handled by a new library called Vismod. Our talented undergraduate, Allen Geer, has been building this library (on top of QT) to address the graph and image display, and user interaction needs of all our modules. We are adapting our SPECTER module (the first module to undergo remodeling) to Vismod for displaying spectral data (with or without spatial context) and annotate with meta data. A visual preference system is being added for quick recall of a presentation state. This will be complete before the grant anniversary. Allen's work is at no cost to this grant. He is supported by internships from the Rice U, and from the PI's startup fund.

Task 4: Applcation of HyperEye algorithms to real scientific data We data mined and classified IMP SuperPan spectral images. This turned out more difficult than originally expected, because of calibration issues: Each octant (a 45-degree segment of the 360-degree SuperPan) is a patchwork of a dozen or so

mosaics each of which may have different viewing geometry and/or instrument characteristics. Repeated calibration efforts could not eliminate these differences. Due to this, signatures of the same material class can be sufficiently different across octants that a classifier trained on "dust" or "rock soil" using one octant will not recognize the same materials in another octant. Only for a few octants did we obtain good enough supervised class maps based on training with prototypes from one reference octant. Those have been interpreted, compared to previous analyses, and presented at LPSC (Farrand *et al.*, 2005). We are preparing a journal paper for Icarus (Farrand *et al.*, 2005b). Ours is the first comprehensive classification of the SuperPan images that were acquired in 1997, due to the difficulties with the data. To cope with the above problem we would need to do full clustering on every octant, label the clusters, perform supervised classification, and then find the corresponding classes across all octants. Cross-matching clusters or classes across multiple images is a tedious, labor intensive, and often difficult task requiring external knowledge. We did this for two octants but do not have resources to do more. Investment in automation of the cross-matching/labeling/interpreting process would yield great returns.

We started to analyze MER images, which are very similar to IMP data, but much cleaner and without the mosaic effect. We expect to submit preliminary results to the next (2006) LPSC.

We have not received Cassini VIMS data so far, for reasons of priority of other urgent activities by the VIMS PI (R. Brown) and team. We plan VIMS analysis for Year 2.

We did more analysis on AVIRIS terrestrial hyperspectral images to map clay-bearing surface units, in support of a landslide hazard assessment project (NASA SE&NH, V. Baker PI, U AZ). We very accurately separated many units and reported results at conferences (Rudd and Merényi, 2004, 2005).

2.2   Publications, presentations, other related activities

Refereed journal and refereed conference proceedings

Farrand, W. H., **Merényi, E.**, Murchie, S., Barnouin-Jha, O. (2005), Spectral Class Distinctions Observed in the MPF IMP SuperPan Using a Self-Organizing Map., Proc. 36th Lunar and Planetary Science Conference, Houston, Texas, March, 2005. , (Extended abstract).

Farrand, W. H., **Merényi, E.**, Bell, J. III, Johnson, J., Murchie, S. and Barnouin-Jha, O. (2005b), Class maps of the Mars Pathfinder landing site derived from the IMP SuperPan: Trends in rock distribution, coatings and far field layering, In preparation.

Merényi, E., (2004), Neural Maps for Precision Data Mining: Application to Planetary Spectral Images, Proc. Jordan Int'l Conference in Computer Science and Engineering, Al-Balqa University, Salt / Amman, Jordan, Oct 4 -7, 2004.

Merényi, E., (2005), Intelligent Understanding of Hyperspectral Images through Self-Organizing Neural Maps, Proc. 2nd Int'l Conf. Cybernetics and Information Technologies, Systems and Applications (CITSA 2005), July 14 - 17, 2005, Orlando, FL, USA. pp. 30 - 35

Merényi, E., Jain, A., Villmann, Th. (2005), Explicit Magnification Control of Self-Organizing Maps for "Forbidden Data", Submitted to IEEE Trans. Neural Networks.

Rudd, L., **Merényi, E.**, (2005), Assessing Debris-Flow Potential by Using AVIRIS Imagery to Map Surface Materials and Stratigraphy in Cataract Canyon, Utah, Proceedings of the Fourteenth Airborne Earth Science Workshop, Pasadena, CA, May 243/427, 2005 (Ed. R.O.Green).

Rudd, L., **Merényi, E.** (2004), The Use of AVIRIS Imagery to Assess Clay Mineralogy and Debris-Flow Potential in Cataract Canyon, Utah, Geological Society of America Abstracts with Programs, 36(5):385 - 385 Posted at http://gsa.confex.com/gsa/2004AM/finalprogram/abstract_79020.htm.

Tasdemir, K., **Merényi, E.**, (2005), Considering Topology in the Clustering of Self-Organizing Maps., Proc. 5th Workshop On Self-Organizing Maps, 5 - 8 September, 2005, Paris, France. Accepted.

Invited Talks by PI

Min(d)ing the spectral aspect: finding patterns in complex, multi-dimensional data with self-organized learning. M. D. Anderson Cancer Center of the University of Texas, Nov 22, 2004.

Information Extraction from Complex Data with Self-Organizing Maps. Philadelphia Seminar on Information Technology, Philadelphia University, Amman, Jordan, Oct 10, 2004

Neural Maps for Precision Data Mining: Application to Planetary Spectral Images. Jordan Int'l Conf. in Computer Science and Engineering, Al-Balqa University, Salt / Amman, Jordan, Oct 7, 2004.

Hyperspectral Eyes on the Solar System: Knowledge Mining the Planets with Computational Intelligence. Tutorial lecture, Jordan Int'l Conference in Computer Science and Engineering, Al-Balqa University, Salt / Amman, Jordan, Oct 4, 2004.

Other presentations by PI and team members / collaborators

Intelligent Understanding of Hyperspectral Images through Self-Organizing Neural Maps. 2nd Int'l Conf. On Cybernetics and Information Technologies, Systems and Applications (CITSA 2005), July 14 - 17, 2005, Orlando, FL, USA.

A Neural Map View of Planetary Spectral Images for Precision Data Mining and Rapid Resource Identification, PI Workshop, NASA AISRP, April 4-7, NASA Ames Research Center

The Use of AVIRIS Imagery to Assess Clay Mineralogy and Debris-Flow Potential in Cataract Canyon, Utah. Conf. Of the Geological Society of America, Colorado Convention Center, Denver, Colorado, Nov 9, 2004 (Rudd, L. and Merényi, E.)

Considering Topology in the Clustering of Self-Organizing Maps. 5th Workshop On Self-Organizing Maps (WSOM 2005), 5 - 8 September, 2005, Paris, France. (Tasdemir and Merényi)

International conference program committees the PI served on

• 6th Jordanian International Electrical & Electronics Engineering Conference (JIEEEC) 2005, November 15 - 17, 2005, Amman, Jordan

• 13th European Symposium on Artificial Neural Networks, ESANN'2005, Bruges, Belgium, April 28-30, 2005

• 1st Jordan Int'l Conference on Computer Science and Engineering (JICCSE 2004), Al Salt (Amman), Jordan, Oct 4 - 7, 2004

2.3   Proposals granted or submitted in this period

• "Neural-Net Analysis of Icy Volatiles in the Solar System" PI Eliot Young, SWRI, Boulder, CO. NASA AISRP, NNG05GA63G, 10/1/2004 to 09/30/2007, $371,367 total budget, $45K/year to Co-I Merényi. Granted.

• Year 3 renewal of "Mapping and Analysis of Spectrally Unique Soils, Rocks and Rock Coatings on Mars at Local and Regional Scales Using Imager for Mars Pathfinder and Mars Odyssey THEMIS", PI W.H. Farrand, Space Science Institute, Boulder, CO. NASA MDAP, NAG5-13294, 4/1/03-3/31/06. $210K total budget, $25/26/6K/yr to Co-I Merényi. Granted.

• Brown Undergraduate Research Internships: Support for one undergraduate student for spring, 2005 semester, and for summer, 2005, from Rice University, School of Engineering. Granted.

- "Examination of the Utility of Spectral Stratigraphy for the Analysis of Stratigraphic Sequences on Mars", NASA Mars Fundamental Research; Program. PI W.H. Farrand, Space Science Institute, Boulder, CO. $324,170 total; $75,000 subcontract to Rice U, for 4/1/2006 - 3/31/2009. Pending.

- "Automatic Labeling of Clusters for Intelligent Understanding of Space and Earth Science Data", NASA AISRP. PI Robert McGrath, NCSA, U Illinois at Urbana Champaign. $418,340 total; $152,642 subcontract to Rice U for 1/01/06 - 12/31/08. Pending.

- " Adaptive Algorithms For Optimal Classification and Compression of Hyperspectral Images", NASA AISRP. PI Tamal Bose, Utah State U. $458,210 total; $168,945 subcontract to Rice U, for 1/01/06 - 12/31/08. Pending.

3   Work Plan for Year 2, 11/1/05 - 10/31/06

Task 1, Work on the main GUI, data handling and other support layers (~25 - 30% effort)

The update of HyperEye modules to use QT and our custom software support components (e.g. Vismod) will continue. History recording of interactive user actions during module operation will be added to these updated modules. Integration of modules with the main GUI will be updated. During Years 2 and 3, expansion of data formats/handling will continue as needed by Co-I data demands (possibly including FITS and PDS formats and URL handling). The website will be updated to use a java-based viewer under which the converted modules can be displayed in a web browser for public demonstration. (Our current web demo is easy to view from unix machines, but it requires a cumbersome communications set up from PCs.) Interested Co-Is (with compatible Sun/unix platforms) may receive module releases in late Year 2 and in Year 3. Continuing on-going activities include special modifications to support algorithmic research by PI and graduate students, maintenance of documentation and test data, and creation of interfaces between HyperEye and Co-I codes.

Task 2, Advancement of ANN/knowledge extraction algorithms (~25–30% effort): We continue the following, as planned: systematic evaluation of the scope of SOM magnification, evaluation of the Villmann topology preservation measure for SOMs, and GRLVQ research for the assessment of the relative importance of hyperspectral data dimensions. We will start systematic evaluation of the Growing Self-Organizing Map (GSOM) by Bauer and Villmann (1997), as planned.

Task 3, Improvement of visualization and human interaction remains a substantial effort ($\sim$ 15%). As planned, the PI and Kadim Tasdemir continue research on automation of cluster boundary extraction from learned SOMs, after considerable success in Year 1. Underlying, QT-based support (VECPLOT and Vismod, written by our undergraduate) will be further exploited. Various visualizations will be turned into plug-ins (for example the rendering of SOM knowledge, the variants of which are now wired into the SOM learning module), so they will be easily applied from any module. With Vismod, the visualization of neural network "objects", data objects and related meta data (annotations) is already possible. Tuning these capabilities and remodeling the data processing modules to use them, will go on in Year 2, as planned.

Task 4, Application of HyperEye to real scientific data will be $\sim$ 30–35% of the effort. With some overlap, we will shift Mars data analysis from Pathfinder to the Mars Exploration Rovers. We will start to work with Cassini VIMS data. We started work on Eliot Young's planetary ice spectra, which will continue in Year 2.

We expect journal publications in Year 2 on SOM magnification; on Mars Pathfinder image classification, and terrestrial hyperspectral image classification. Conference submissions are expected on GRLVQ, topology preservation, and MER image analysis.

4   References

Some of the PI's papers are downloadable at http://www.ece.rice.edu/~erzsebet/publications.html

Bauer, H.U., Der. R., Herrmann, M. (1996), Controlling the Magnification Factor of Self-Organizing Feature Maps, Neural Computation, 8:757–771.

Bauer, H.U., and Villmann, Th. (1997), Growing a Hypercubical Output Space in a Self-Organizing Feature Map, IEEE Trans. on Neural Networks, 8(2):218-226.

Cottrell, M., de Bodt, E., (1996), A Kohonen Map Representation to Avoid Misleading Interpretations, European Symposium on Artificial Neural Networks, Bruges, Belgium, 22–24 April, 1996.

DeSieno, D. (1988), Adding a Conscience to Competitive Learning, Proc. ICNN New York, July 1988, I:117–124.

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Hammer, B., Villmann, Th. (2002), Generalized relevance learning vector quantization, Neural Networks, 15:10593/41068.

Jain, A., **Merényi, E.**, (2004), Forbidden Magnification? I., Proc. 12th European Symposium on Artificial Neural Networks, ESANN'2004, Bruges, Belgium, 28–30 April, 2004. pp. 51 - 56

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Merényi, E., Jain, A., Villmann, Th. (2005), Explicit Magnification Control of Self-Organizing Maps for "Forbidden Data", Submitted to IEEE Trans. Neural Networks

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Ultsch, A., and H. P. Siemon, (1990), Kohonen's Self Organizing Feature Map for Exploratory Data Analysis, Proc. INNC-90-PARIS. pp. 305-308

Villmann, Th., Herrmann, R.Der, and Martinetz, Th. (1997), Topology Preservation in Self-Organizing Feature Maps: Exact Definition and Measurement, IEEE Trans. on Neural Networks, 8(2):256–266.

Villmann, T.,**Merényi, E.**, Hammer, B. (2003), Neural Maps in Remote Sensing Image Analysis, Neural Networks, Special Issue on Neural Networks for Analysis of Complex Scientific Data, 16:(3–4):389-403.

5   Appendix: Acronyms

ANN	Artificial Neural Network
AVIRIS	Airborne Visible and Infrared Imaging Spectrometer, of NASA, JPL
AVIRISLA	Low-Altitude AVIRIS
BDH	algorithm for SOM magnification control by Bauer, Der and Herrmann (1996)
BP	Back Propagation, an ANN paradigm
EO-1	Earth-Observing satellite, NASA
GSOM	Growing Self-Organizing Map, an ANN paradigm
HST	Hubble Space Telescope
HYDICE	Hyperspectral Digital Image Collection Experiment, Naval Research Lab
IMP	The Imager for Mars Pathfinder
Landsat TM	Landsat Thematic Mapper
Landsat MSS	Landsat Mulstispectral Scanner
LPL	Lunar and Planetary Laboratory; at University of Arizona
MER	Mars Exploration Rovers
MGS	Mars Global Surveyor
ML	Maximum Likelihood classifier
PCA	Principal Components Analysis
SOM	Self-Organizing Map, a neural network paradigm
STIS	Space Telescope Imaging Spectrograph
UA	University of Arizona
VIMS	Visible-Infrared Mapping Spectrometer, Cassini mission

6   Budget for Year 2

Our budget, attached, for Year 2 remains as it was approved.

YEAR 2

Fiscal Year Ratios   A= 0.6666667 B= 0.3333333

Percent of total year which is off campus	2006 FY-A Off-campus	2007 FY-B Off-campus	2006 FY-A On	2007 FY-B On	Total For Year 2
			12,655	6,327	18,982
			12,655	6,327	18,982
			26,554	13,277	39,831
			16,467	8,233	24,700
			55,676	27,837	83,513
			16,711	8,355	25,066
			72,387	36,192	108,579
			6,200	6,200	
			7,300	7,300	
			447	223	670
			933	467	1,400
			2,533	1,267	3,800
			7,321	3,661	10,982
			11,235	5,617	16,852
			83,621	55,310	138,931
			39,456	26,612	66,068
			123,077	81,922	204,999
			123,077	81,922	204,999
MTDC			77,364	52,181	129,545
GSTR			6,257	3,129	9,386
	Off-campus	Off-campus	On-campus	On-Campus	Total

SUMMARY PROPOSAL BUDGET	Year 2					
ORGANIZATION William Marsh Rice University				PROPOSAL NO.	DURATION (MONTHS)	
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Erzsebet Merenyi				AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with name and title. (A.7. Show number in brackets)	Person-months			Funds Requested By Proposer	
	CAL	ACAD	SUMR		
1. Erzsebet Merenyi			1.70	$ 18,982	
2. Robert H. Brown					
3. William H. Farrand					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. (3) TOTAL SENIOR PERSONNEL (1-6)			1.70	18,982	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POST DOCTORAL ASSOCIATES					
2. (1) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	9.00			39,831	
3. (2) GRADUATE STUDENTS total of 13.0 months				24,700	
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A+B)				83,513	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS) See the budget attachment for explanation				25,066	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				108,579	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				6,200	
2. FOREIGN				7,300	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $					
2. TRAVEL					
3. SUBSISTENCE					
4. OTHER					
TOTAL NUMBER OF PARTICIPANTS) TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				670	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				1,400	
3. CONSULTANT SERVICES					
4. COMPUTER SERVICES				3,800	
5. SUBAWARDS				10,982	
6. OTHER					
TOTAL OTHER DIRECT COSTS				16,852	
H. TOTAL DIRECT COSTS (A THROUGH G)				138,931	
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) See Budget Attachment					
TOTAL INDIRECT COSTS (F&A)				66,068	
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				204,999	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECTS SEE GPG II.D.7.j.)					
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				$ 204,999	$
M. COST SHARING: PROPOSED LEVEL $		AGREED LEVEL IF DIFFERENT: $			
PI/PD TYPED NAME & SIGNATURE* Erzsebet Merenyi	DATE				
INST. REP. TYPED NAME & SIGNATURE* Jordan Konisky, Vice Provost for Research and Graduate Studies	DATE				